

Solar System Ambassadors+
August 22, 2016

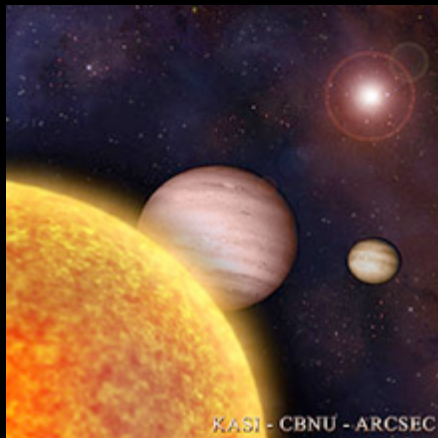
Life in the Universe: The Science of Astrobiology

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What is Astrobiology?

Study of the potential
of the Universe to
harbor life beyond
Earth



The background of the image is a detail from Raphael's fresco 'The School of Athens'. It depicts the philosophers Plato and Aristotle standing in the center, facing each other. Plato, on the left, is an older man with a long white beard, wearing a red robe, pointing his right index finger towards the sky. Aristotle, on the right, is a younger man with dark hair, wearing a blue robe, gesturing with his right hand palm-down towards the earth. They are surrounded by other philosophers in a grand, classical architectural setting with arches and columns. The floor has a geometric tile pattern.

This has been pondered by
philosophers...

***“There are infinite worlds both like and unlike
this world of ours...We must believe that in
all worlds there are living creatures and
plants and other things we see in this world.”***

Epicurus (c. 300 B.C.)

...and theologians



St. Thomas Aquinas (13th Cent.)

“When it is said...that many worlds are better than one, ... this sort of better...does not belong to the intention of God...because for the same reason it could be said that if he made two, it would be better that there were three; and thus ad infinitum.”

Today astrobiology addresses three fundamental scientific questions

- How does life begin and evolve?

- Does life exist elsewhere in the universe?

- What is the future of life on Earth and beyond?

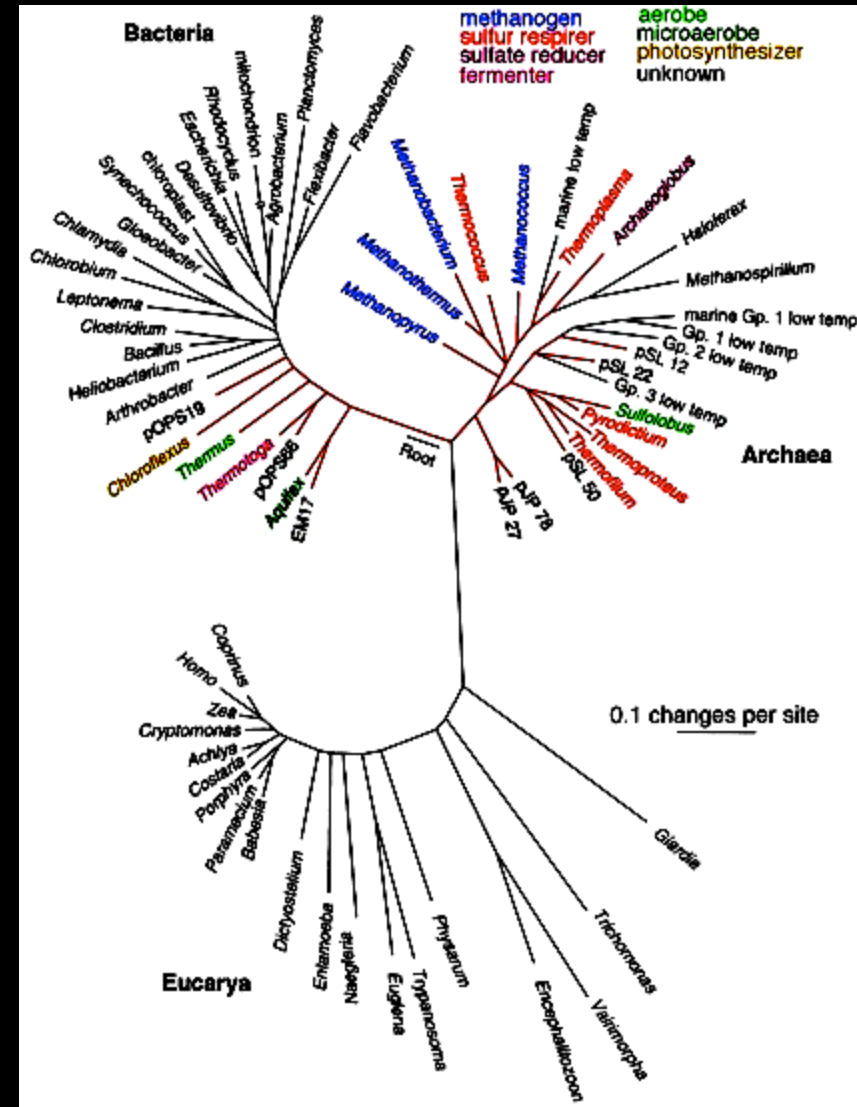
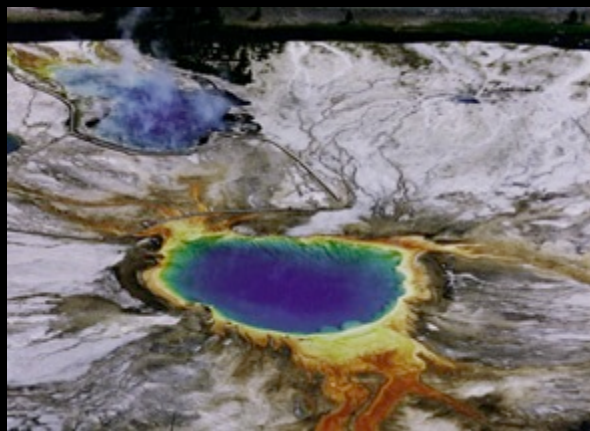
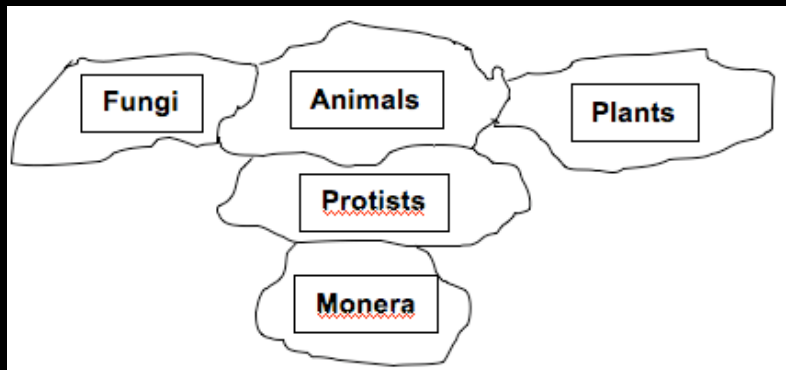
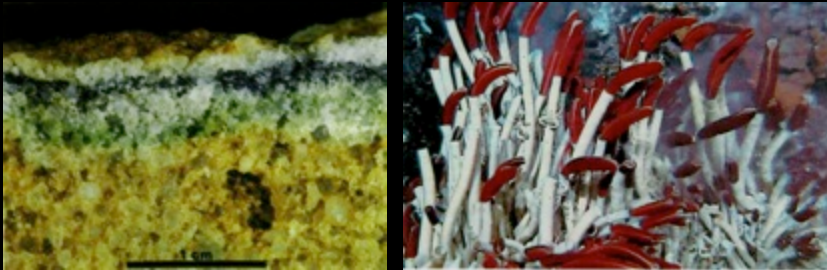




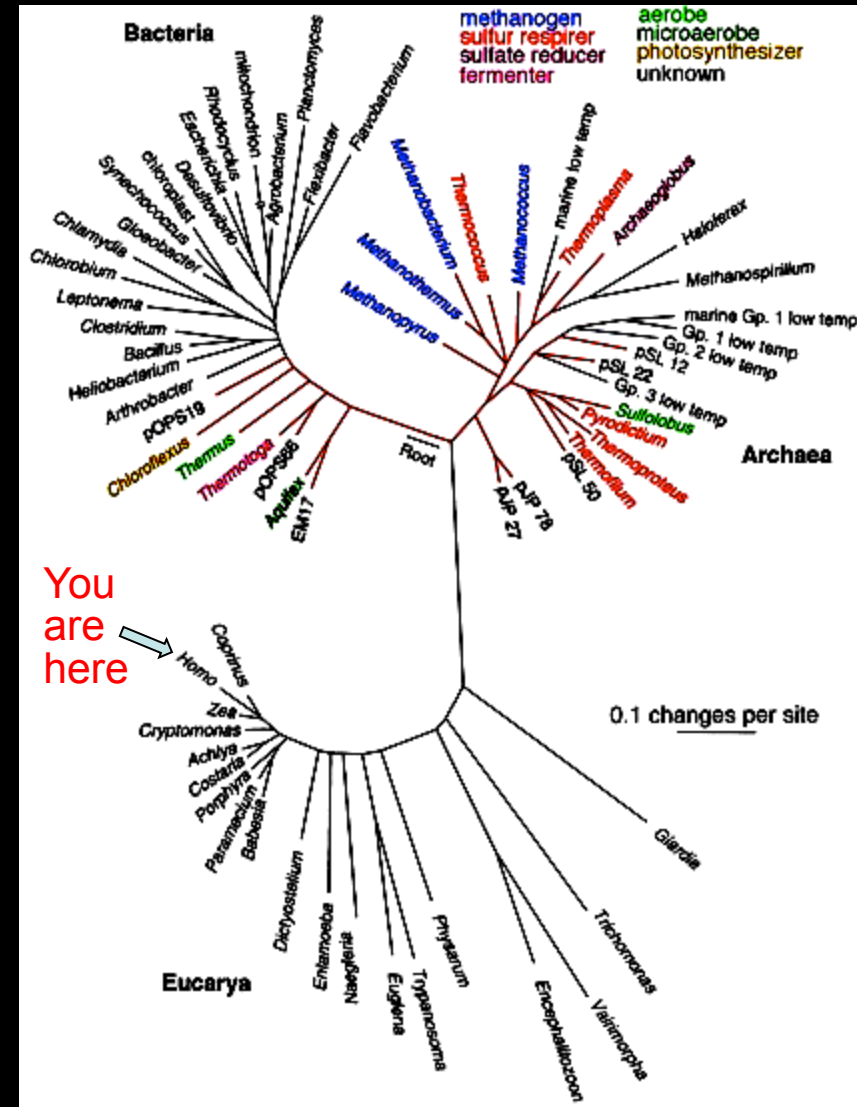
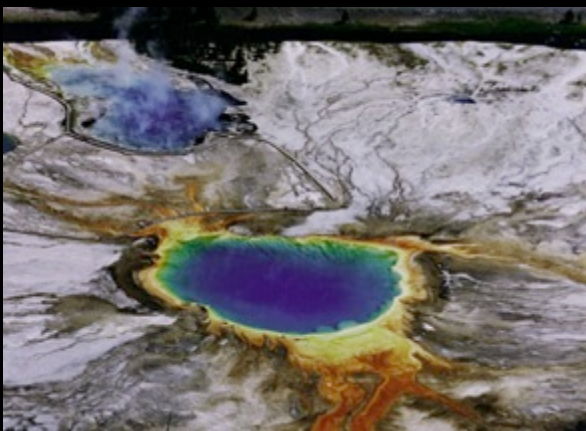
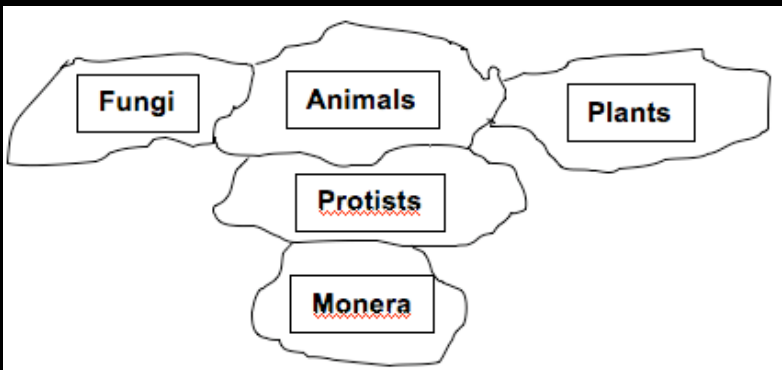
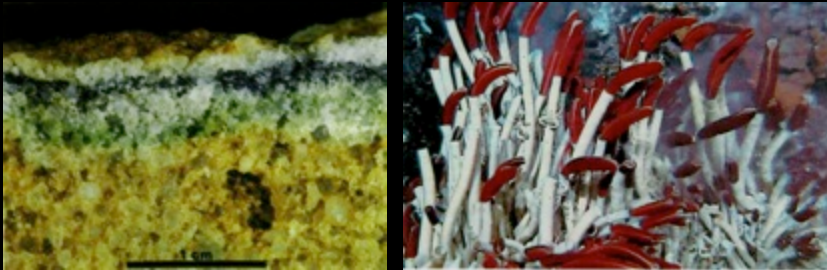
Five Interconnected Areas of Science

1. Diversity of life on modern Earth
2. The co-evolution of life and our planet
3. Diversity of Solar System environments
4. Planetary environments around other stars
5. The origin of life
 - a. Where and how the raw ingredients for life are made
 - b. How a world may transform from non-living to living

1. The Diversity of Life on Earth



1. The Diversity of Life on Earth



Metabolic Diversity

THERMODYNAMICS

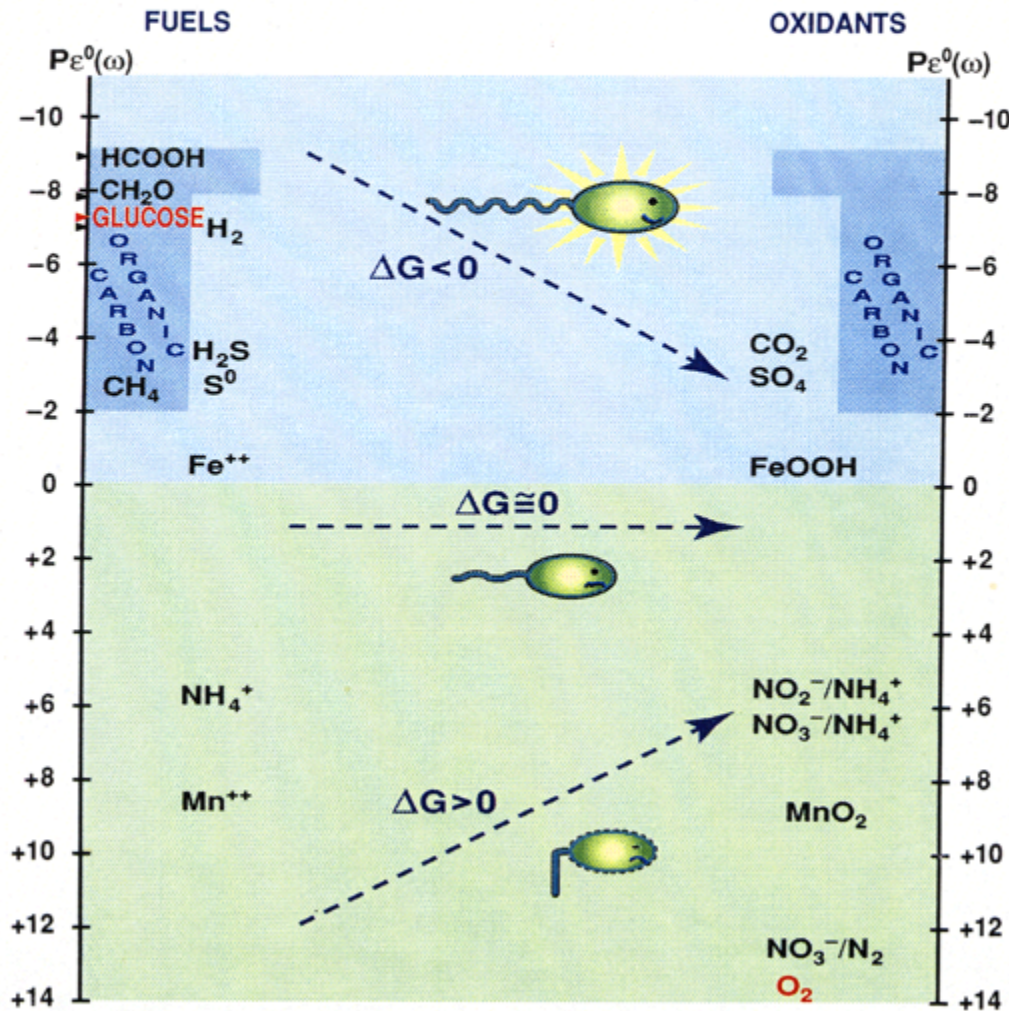
IT'S NOT JUST A GOOD IDEA... IT'S THE LAW

6LJ20L-2

Most
Energy
(chocolate!)

Reductants

Least
Energy
(celery!)



Worst
Oxidant

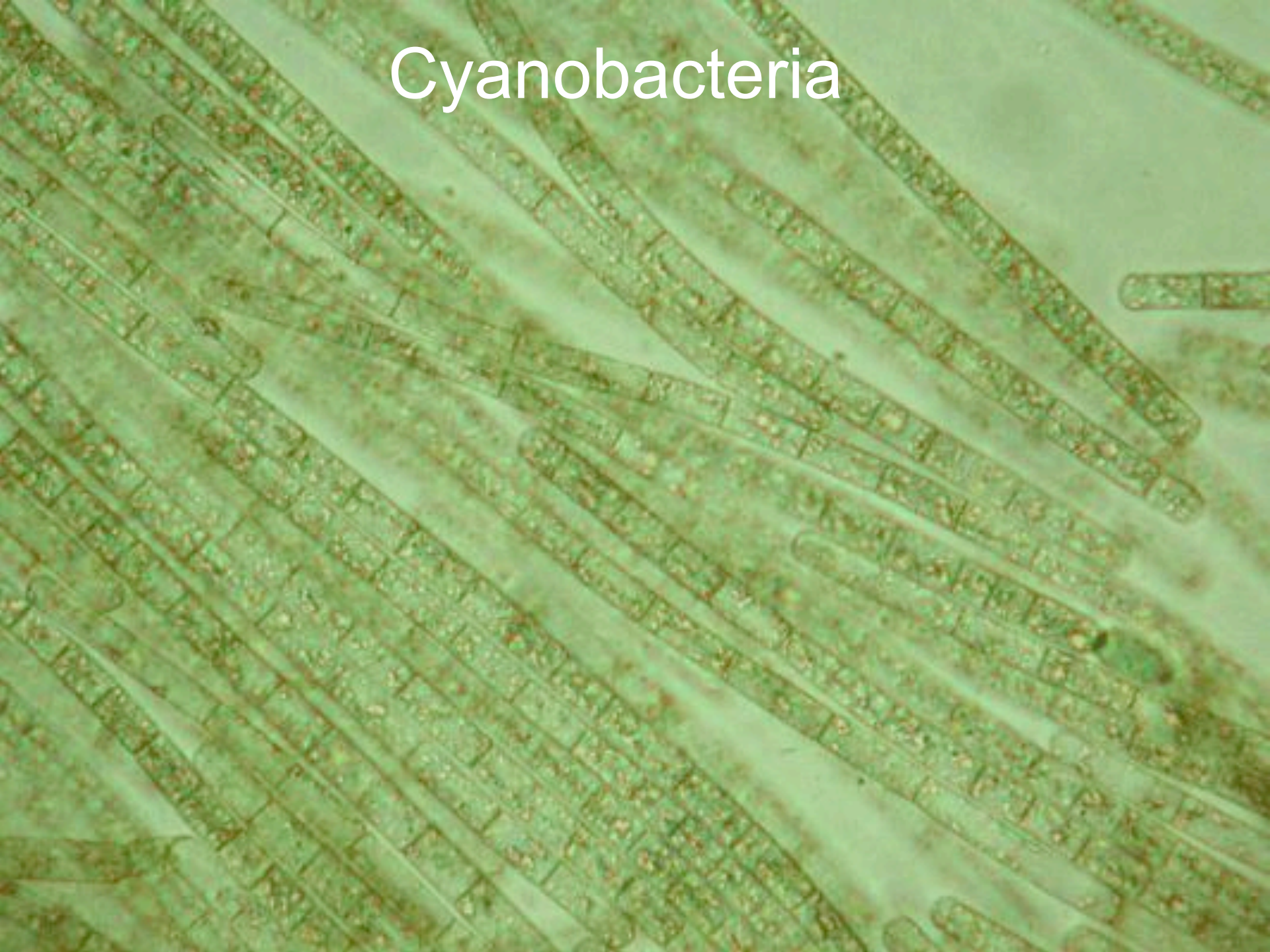
Best
Oxidant

2. Co-evolution of life and the Earth

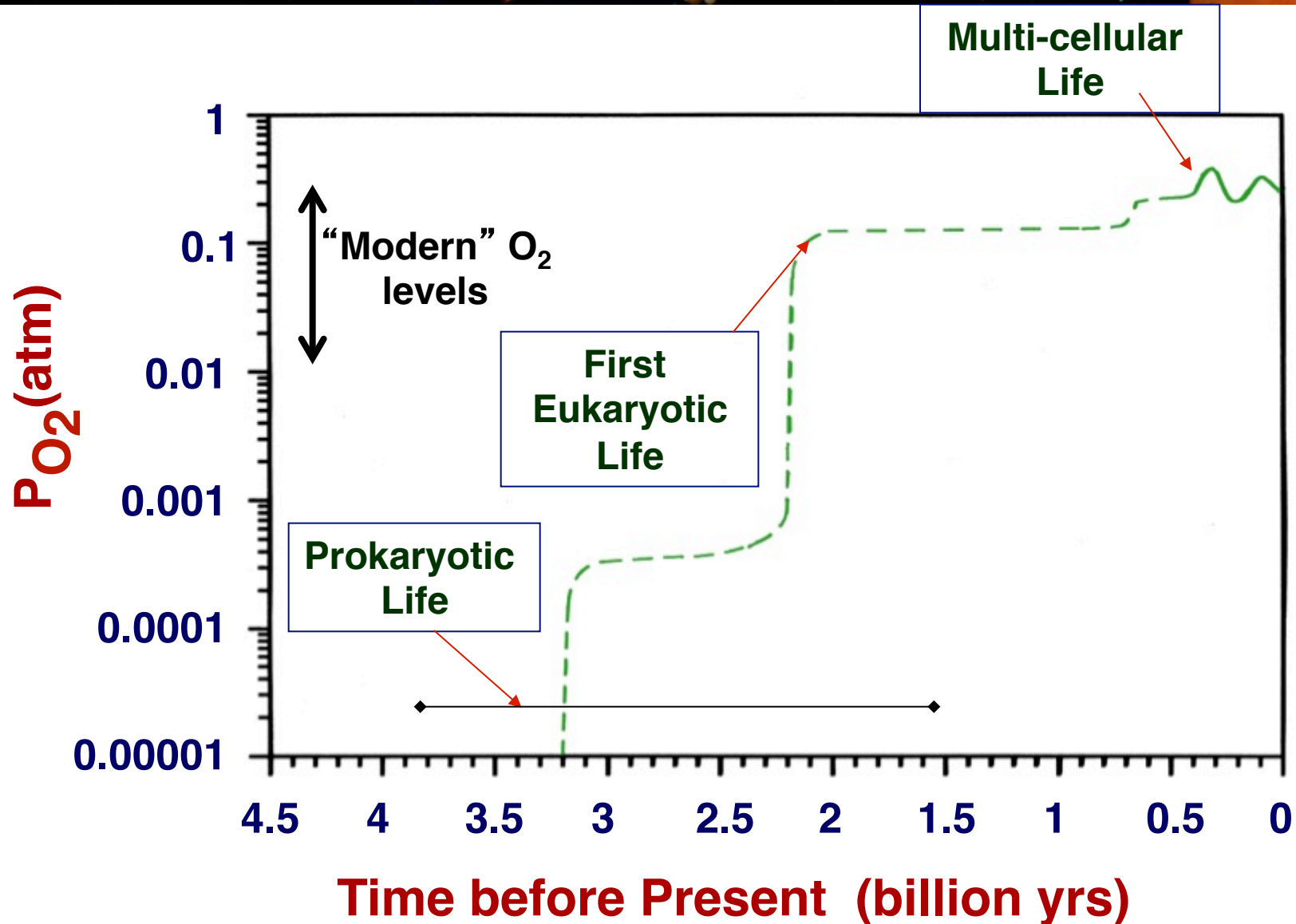
Stromatolites: Ancient and modern



Cyanobacteria



History of Oxygen

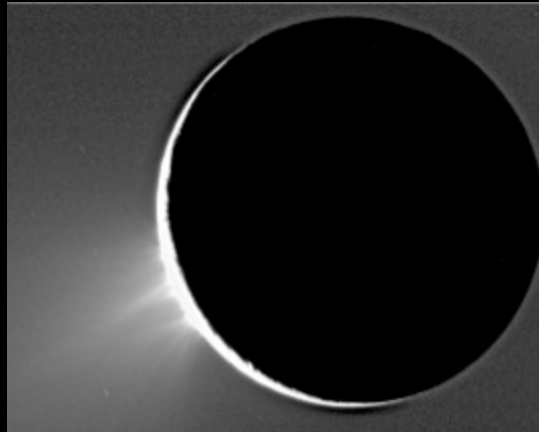


3. The Diversity of Solar System Environments

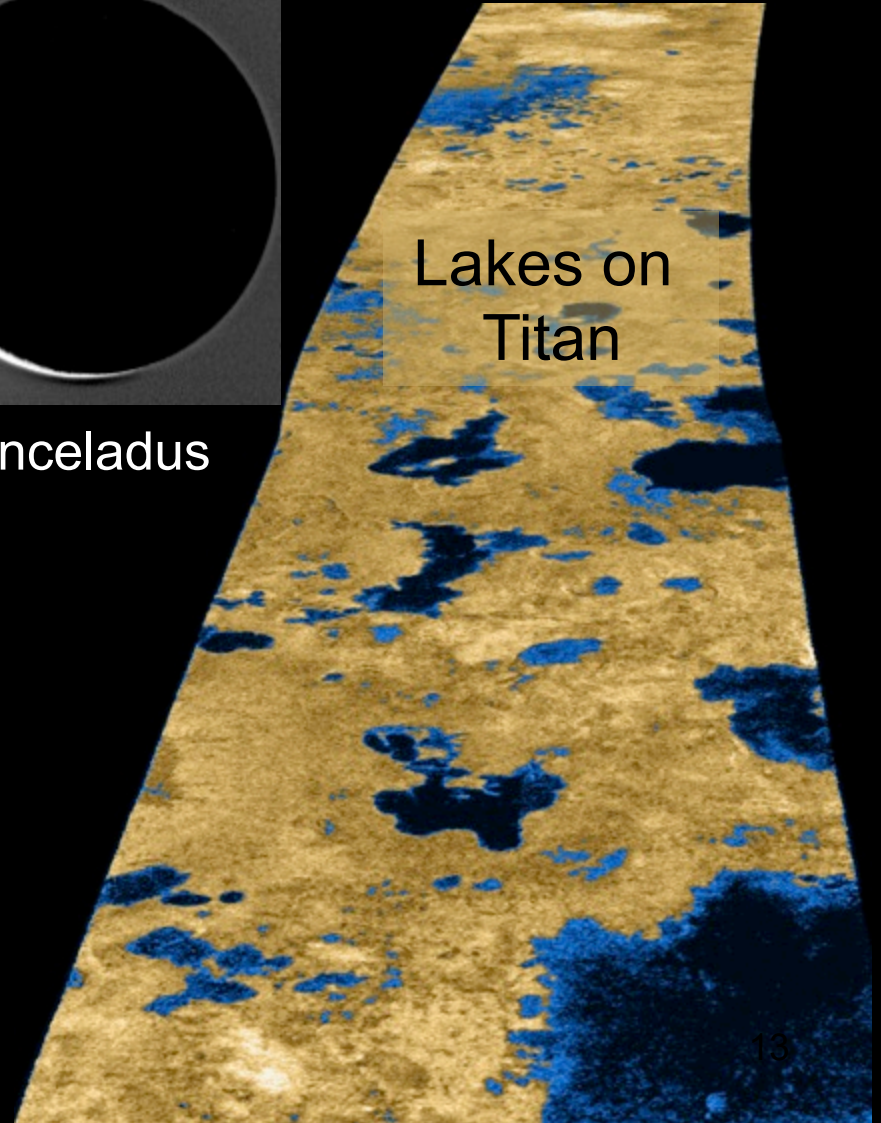
Mars



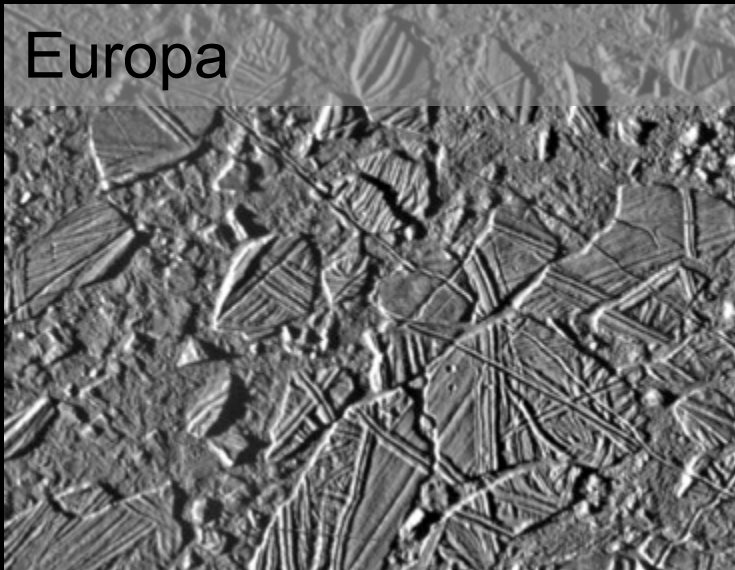
Jets on Enceladus



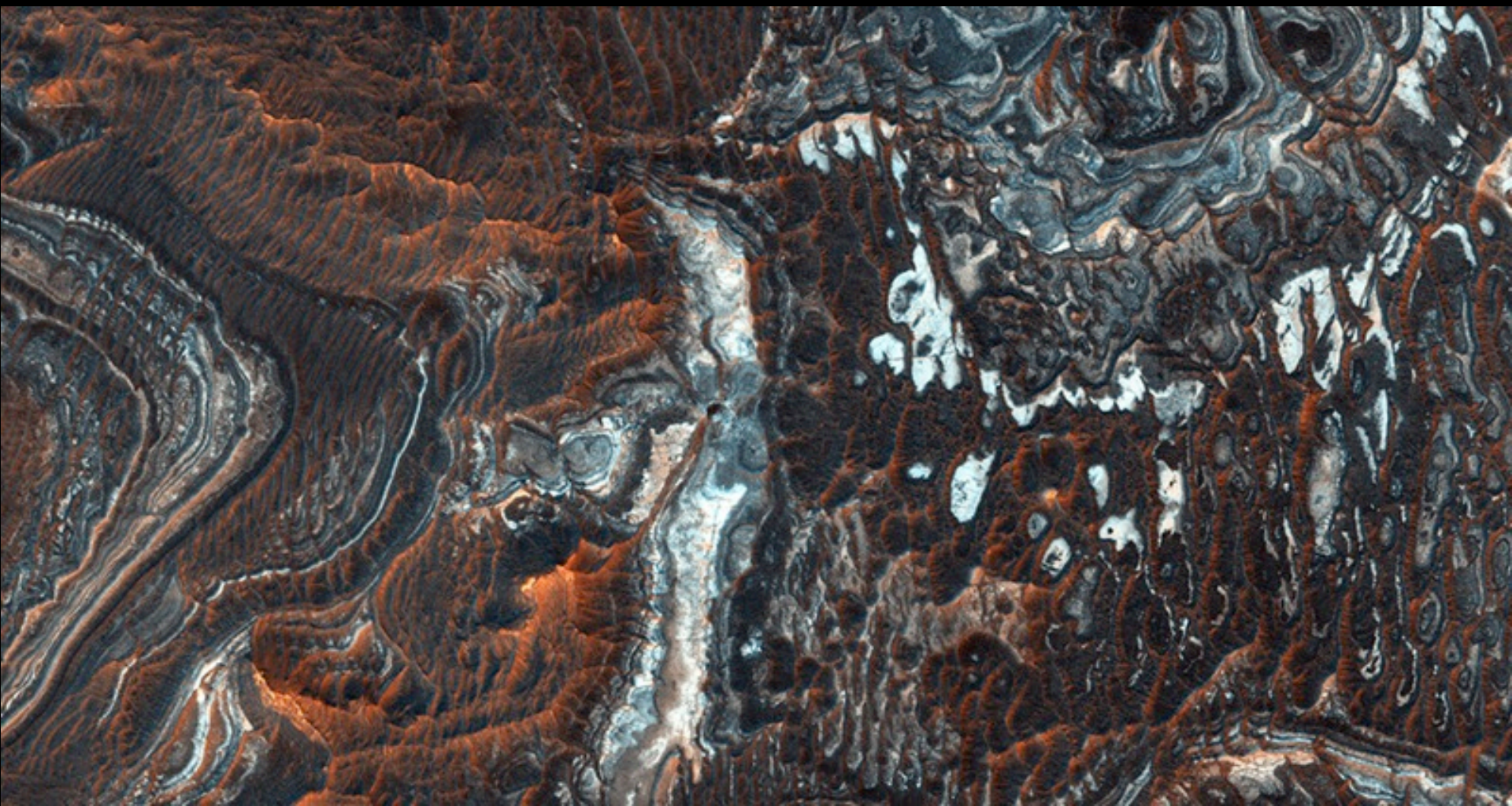
Lakes on Titan



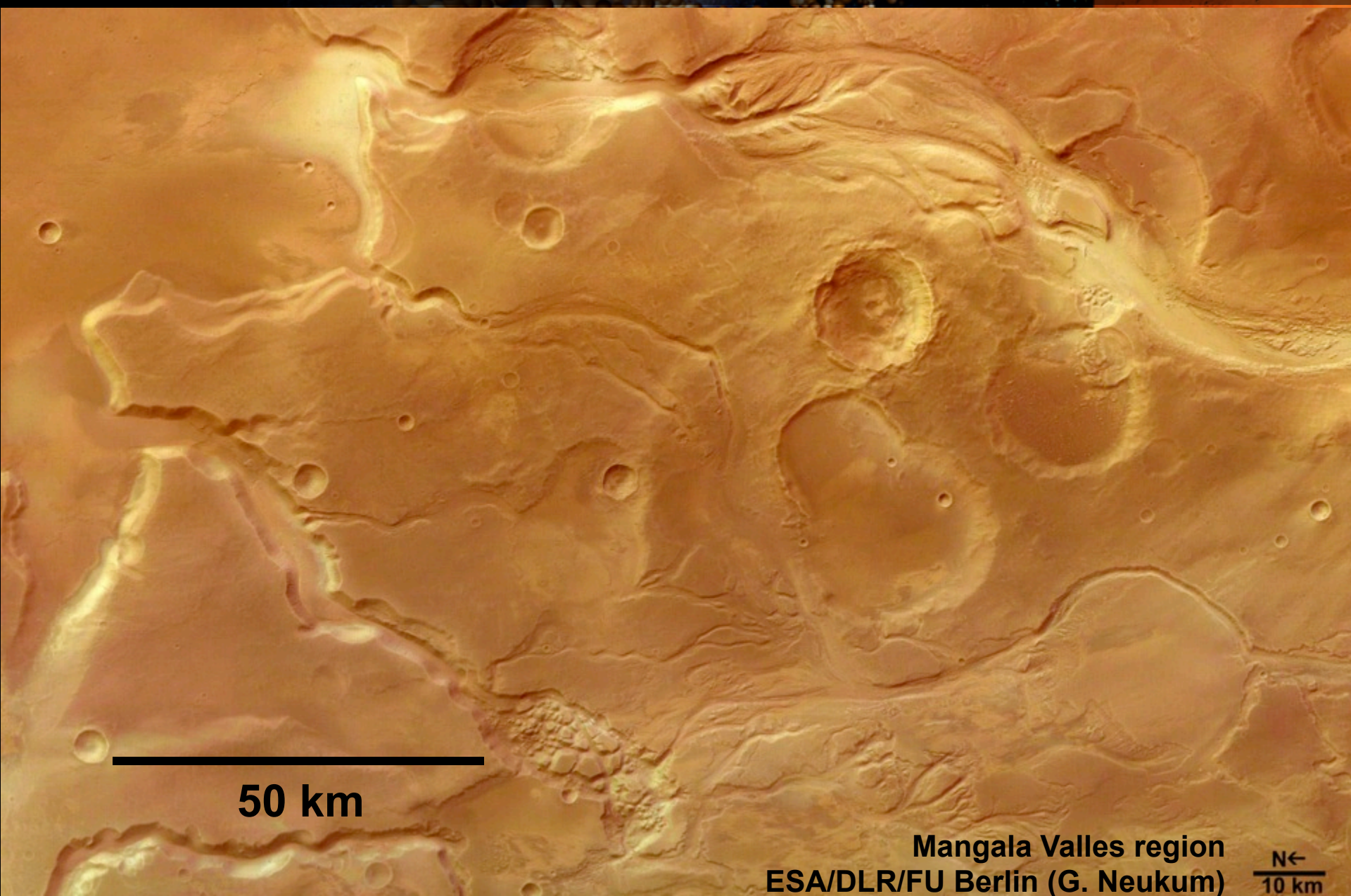
Europa



Mars – Juventae Chasma



Enormous dry river systems indicate that large volumes of water flowed across Mars billions of years ago

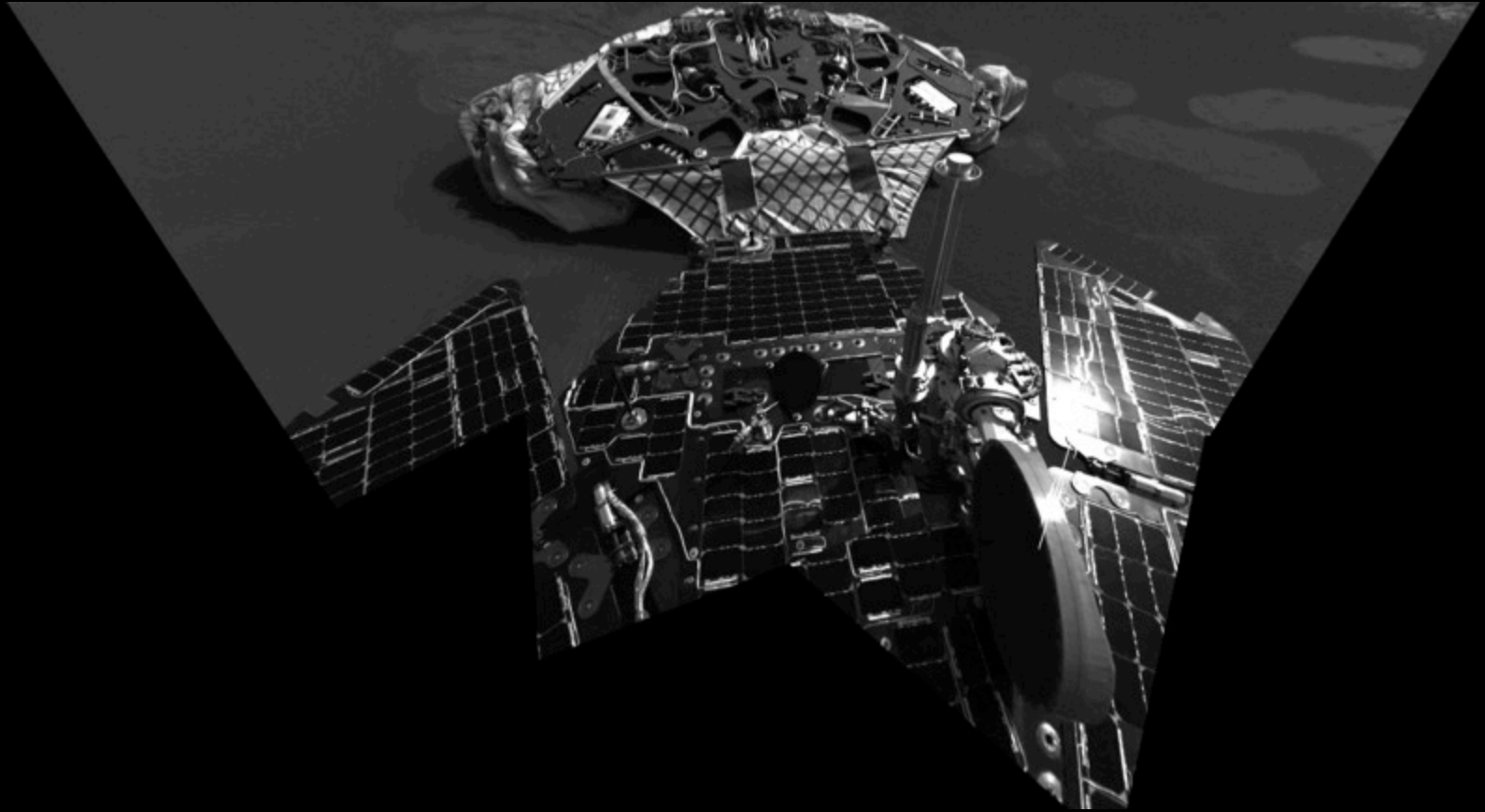


50 km

Mangala Valles region
ESA/DLR/FU Berlin (G. Neukum)

N
10 km

Opportunity Rover Lands on Mars (2004)



“Blueberry Bowl” (enhanced color)



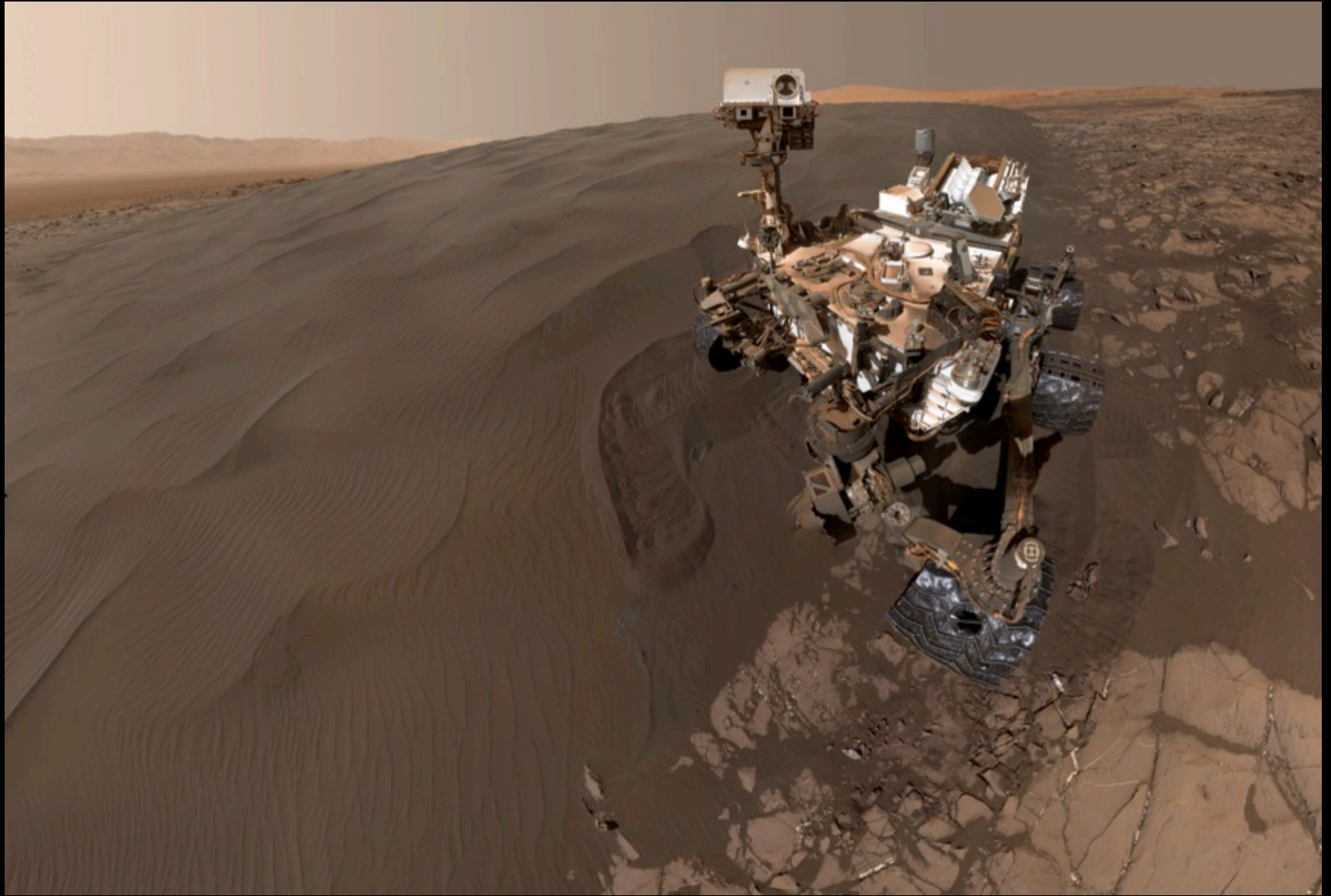
Ice under Phoenix Lander



Liquid (saline) droplets on Phoenix lander strut



Curiosity "Selfie" (2016)



Streambed Deposits



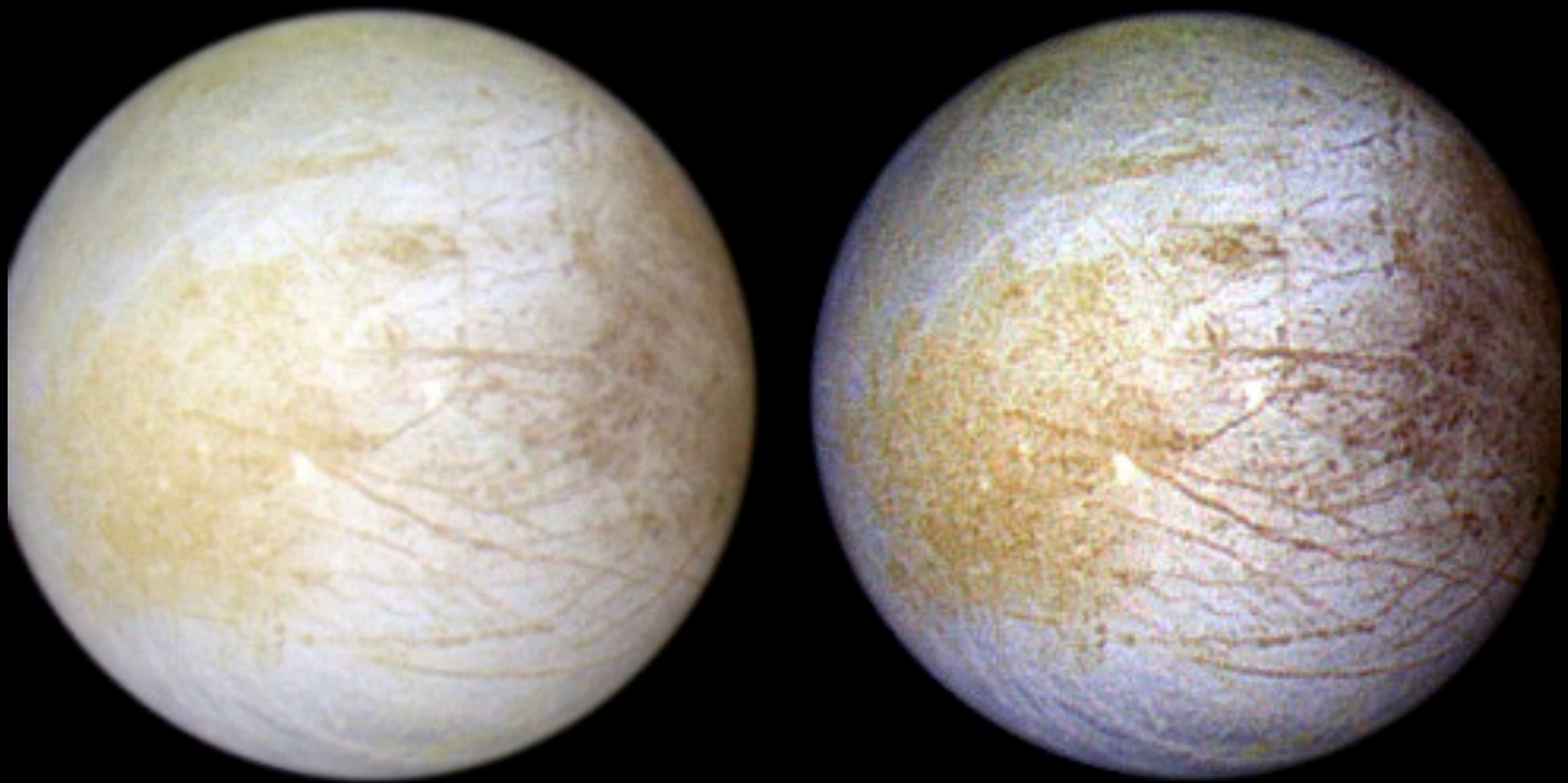
5 cm

Mt. Sharp Foothills

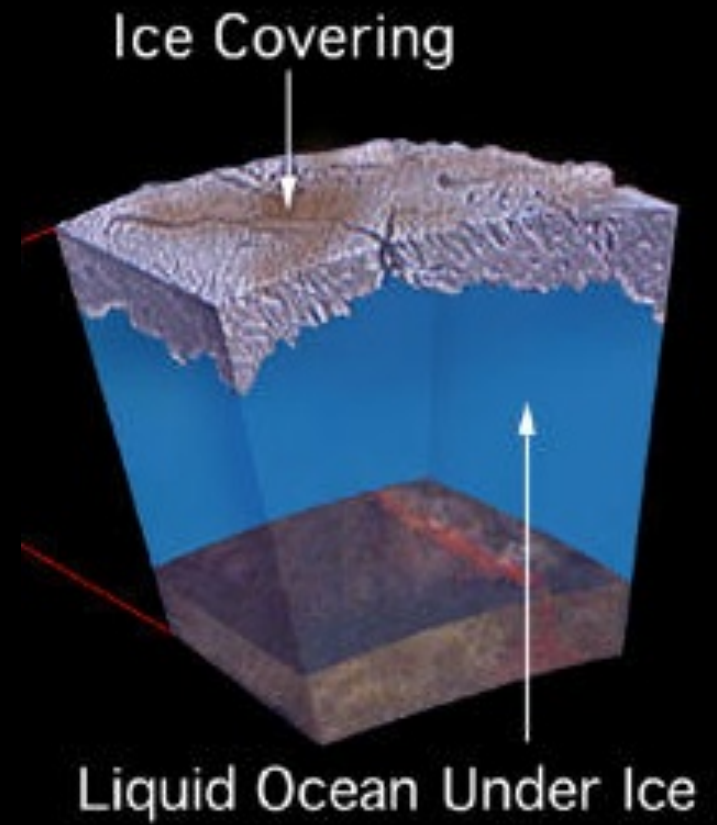
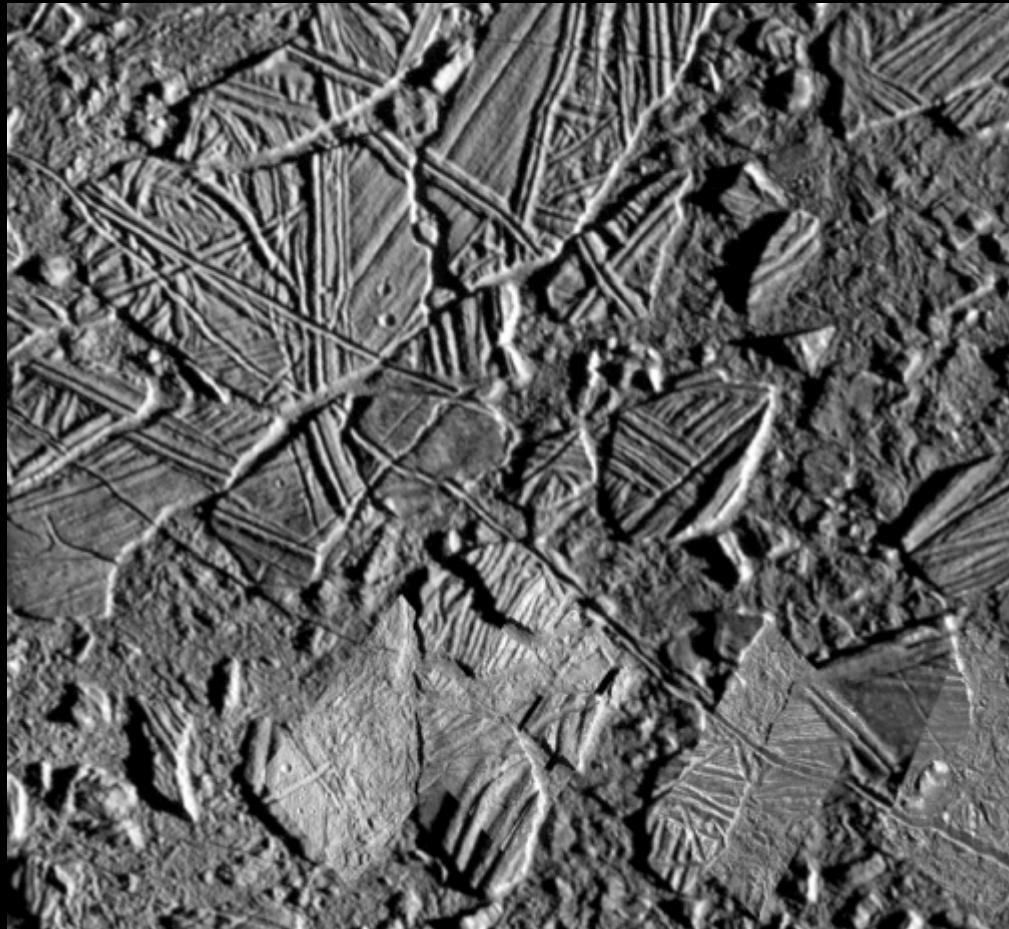




Europa (moon of Jupiter)



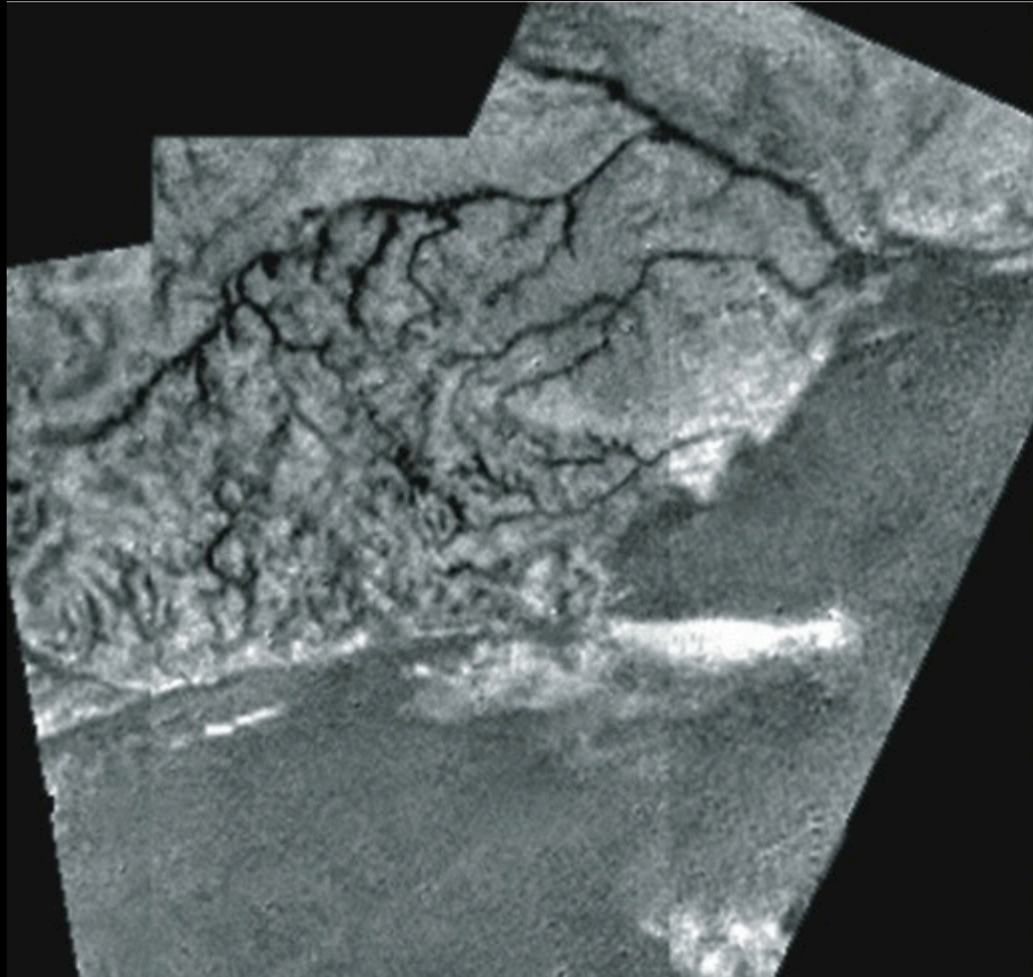
Europa



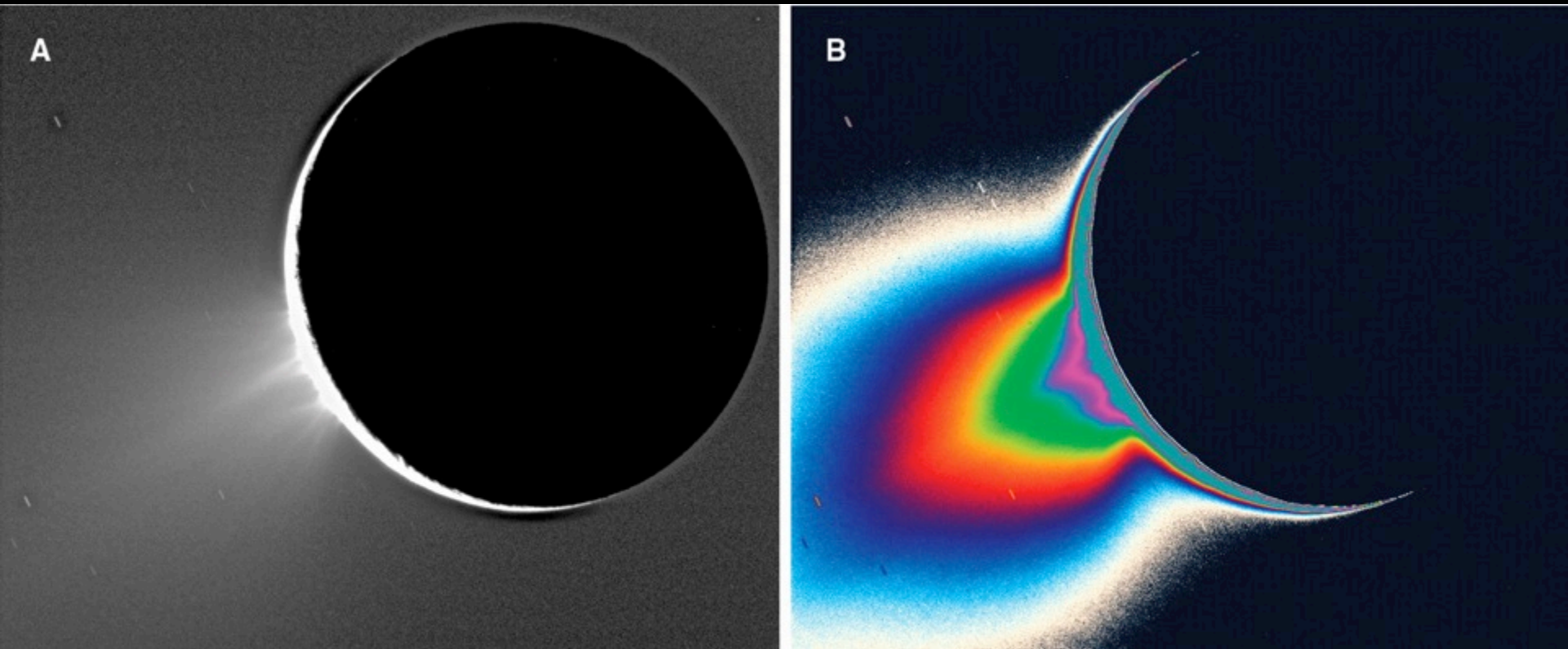
Titan (moon of Saturn)



A Hidden World



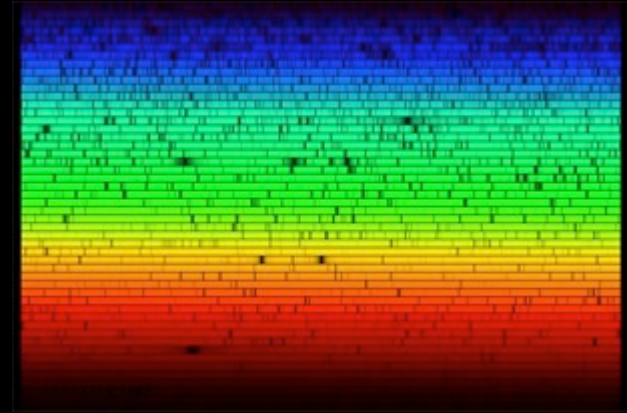
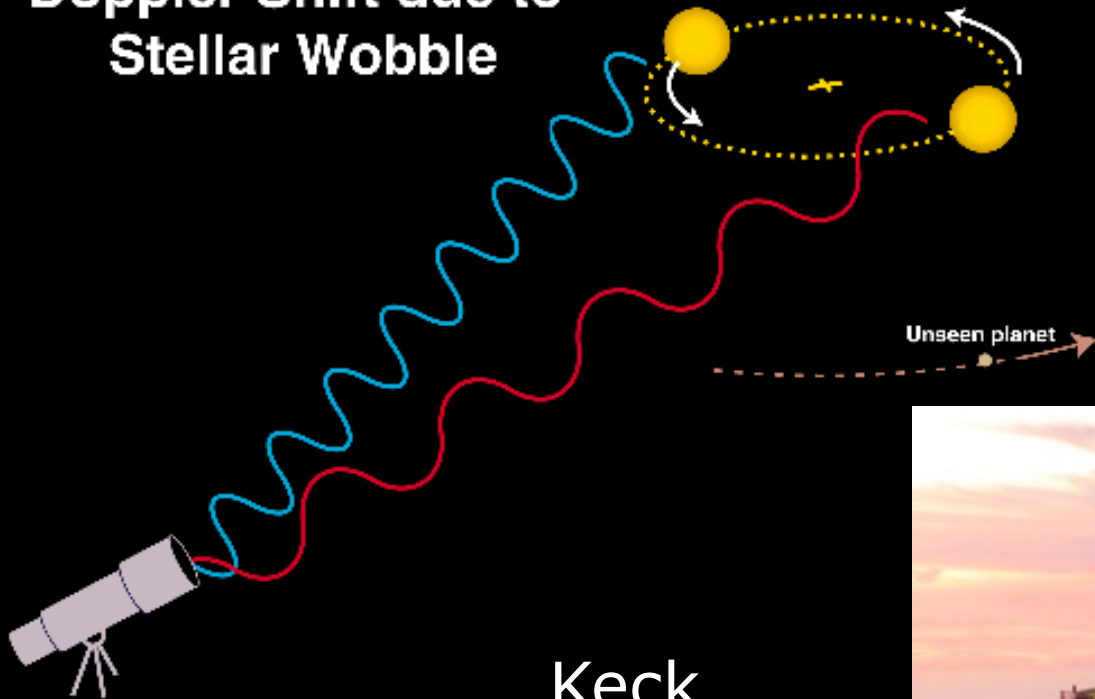
Jets of H₂O (+salts, organics) on Enceladus



4. Planets Around Other Stars

Doppler Method

Doppler Shift due to
Stellar Wobble

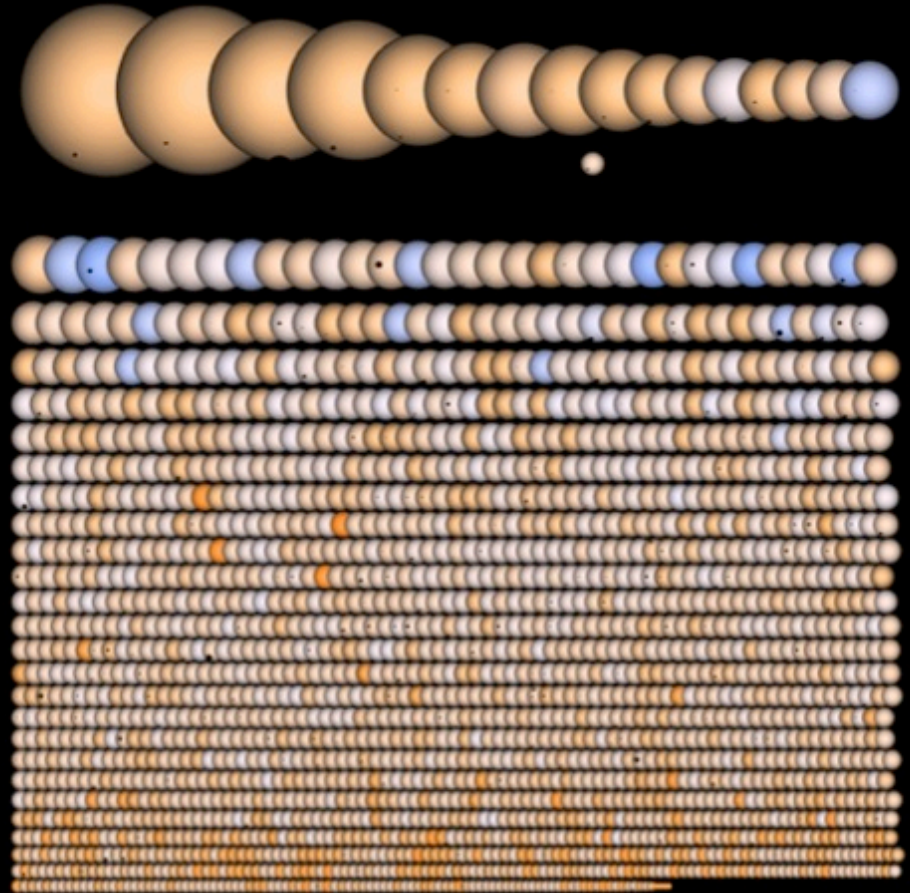
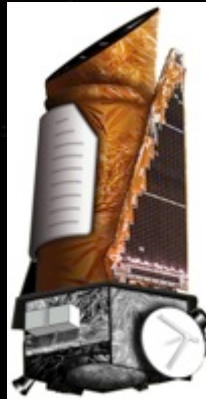
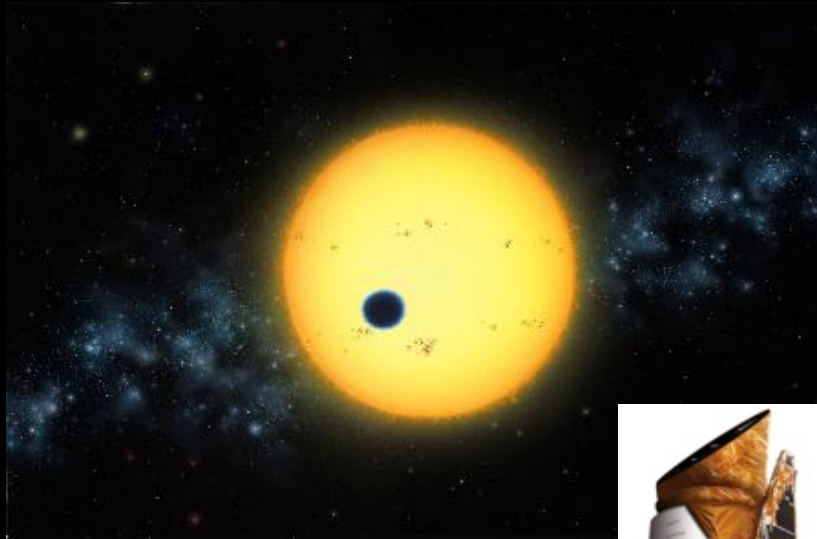


Keck
Observatory
Mauna Kea,
Hawai'i



4. Planets Around Other Stars

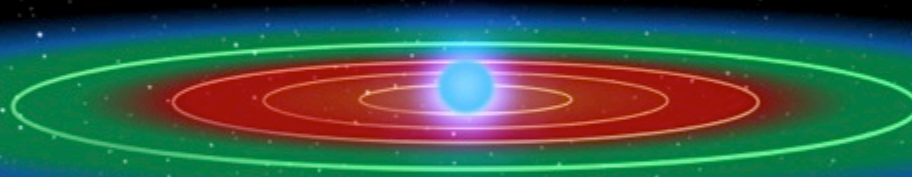
Transit Method



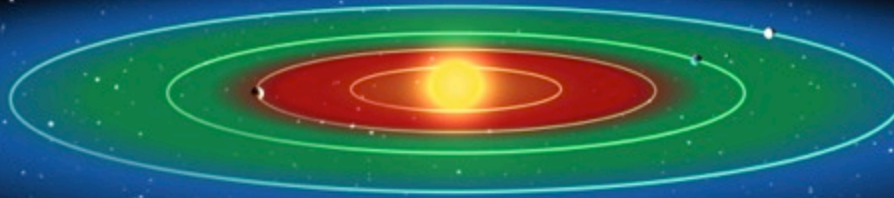
Kepler Planet Candidates

The Habitable Zone

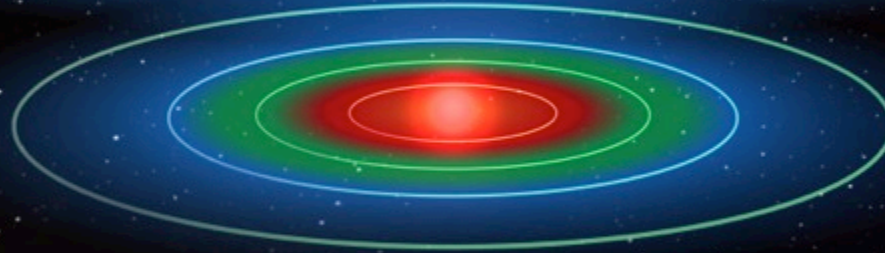
Hotter Stars



Sunlike Stars



Cooler Stars

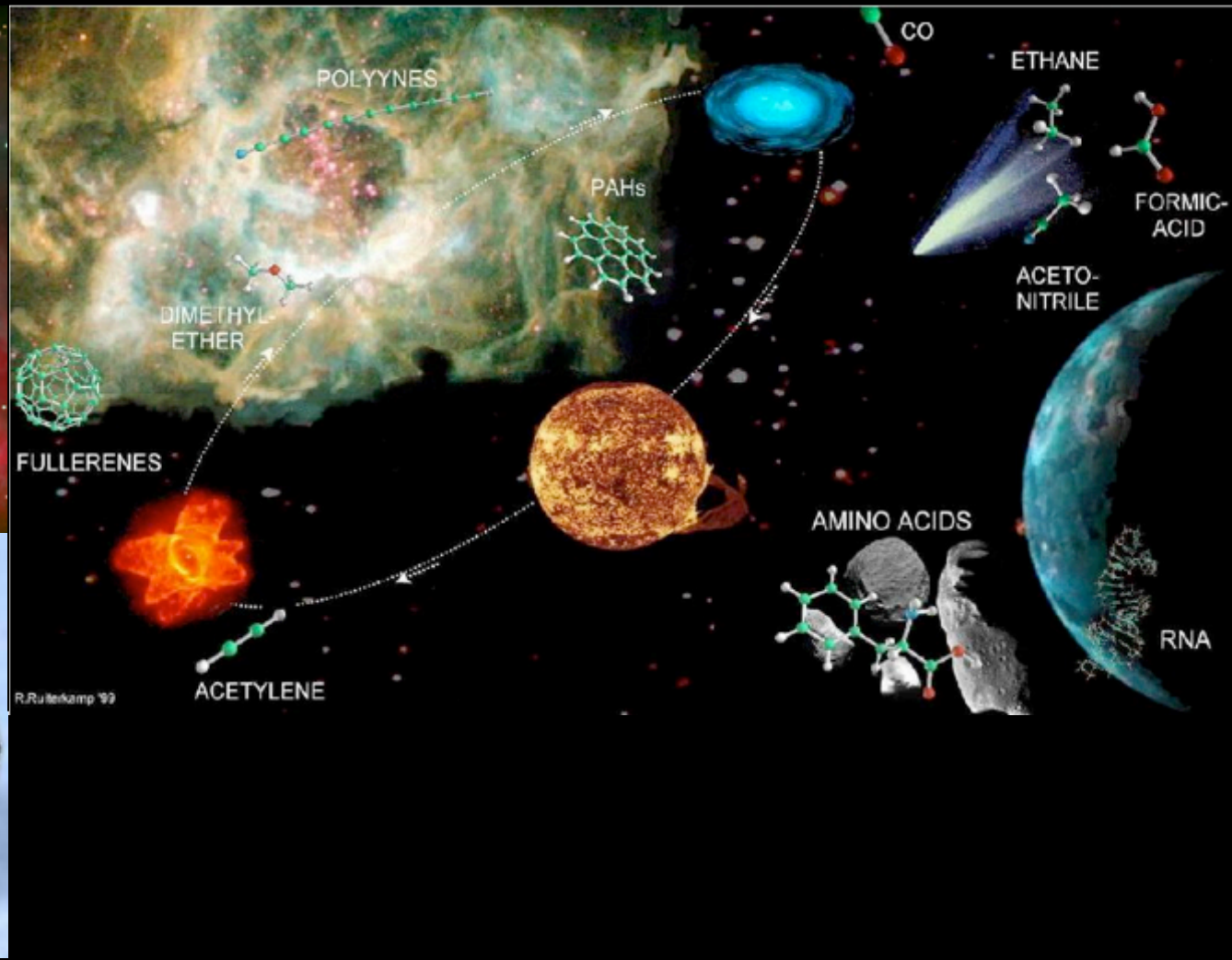


$22 \pm 8 \%$ of Sun-like stars harbor an Earth-size planet in Habitable Zone

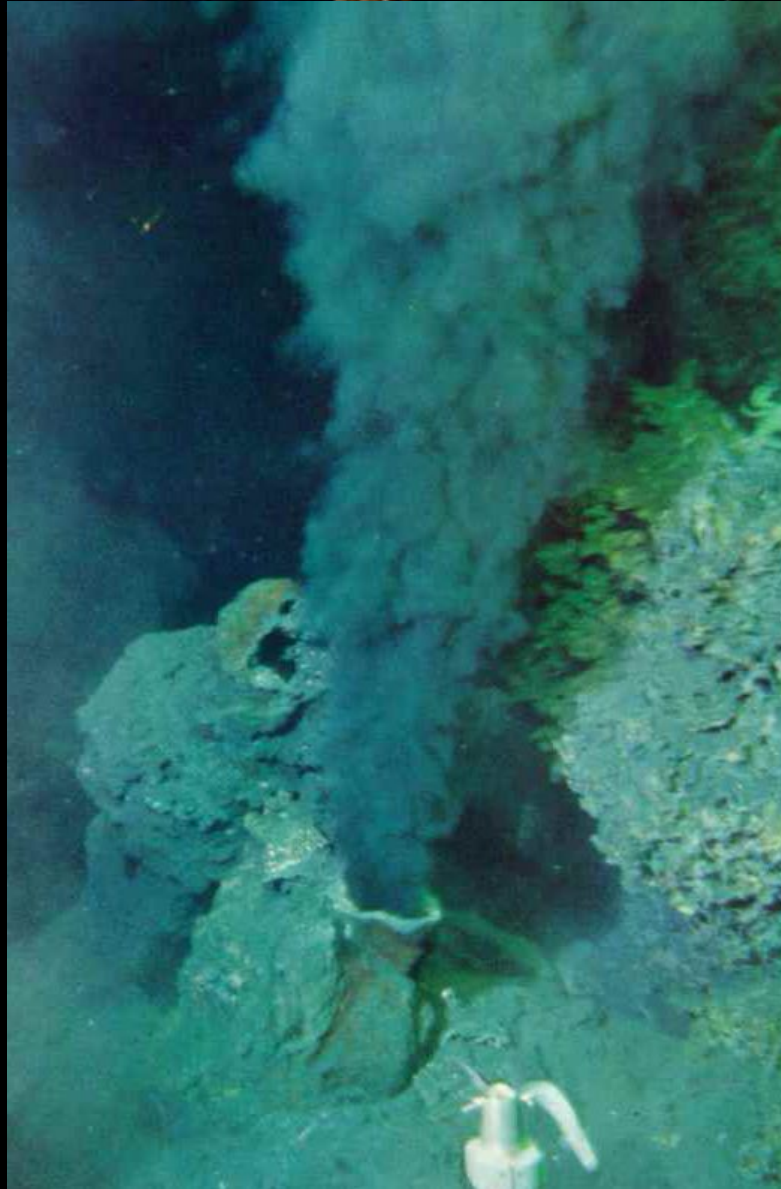


5. Origin of Life

Raw materials from space?



Could Life Have Arisen at a Hydrothermal Vent?



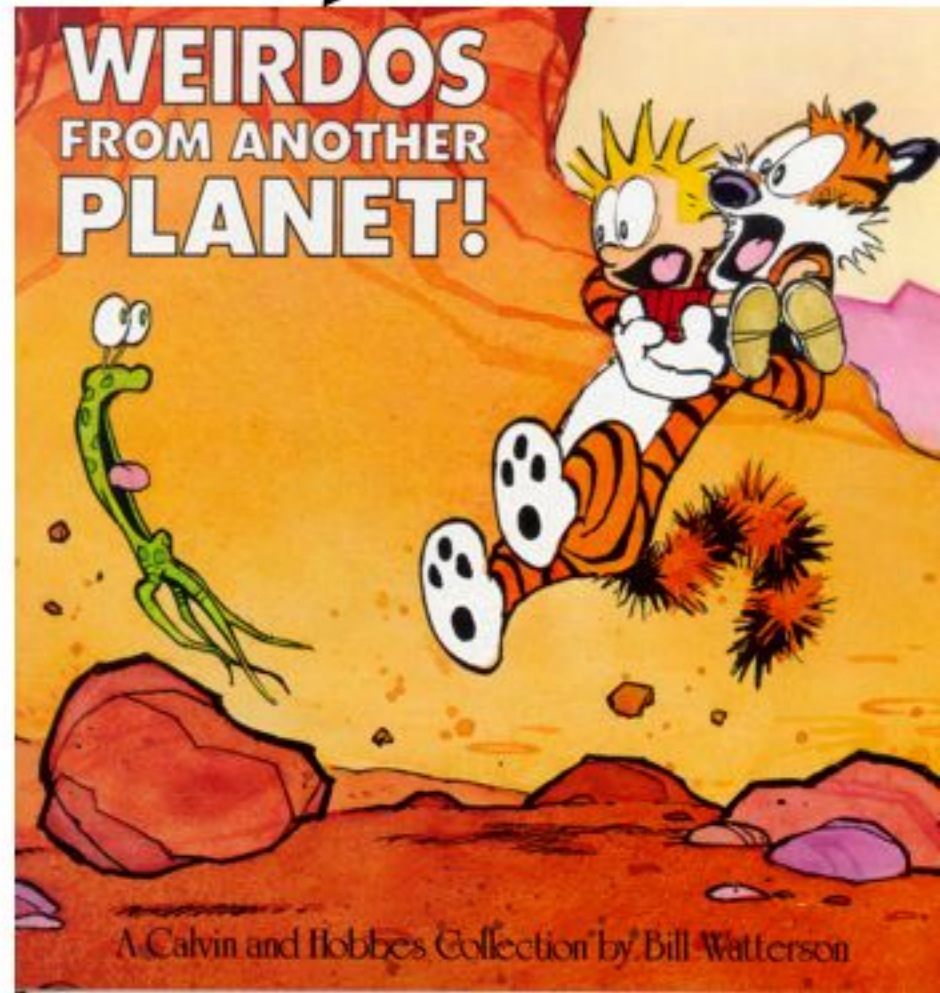
Or in a tide pool?



How do we recognize alien life?



we'll know it when we see it!

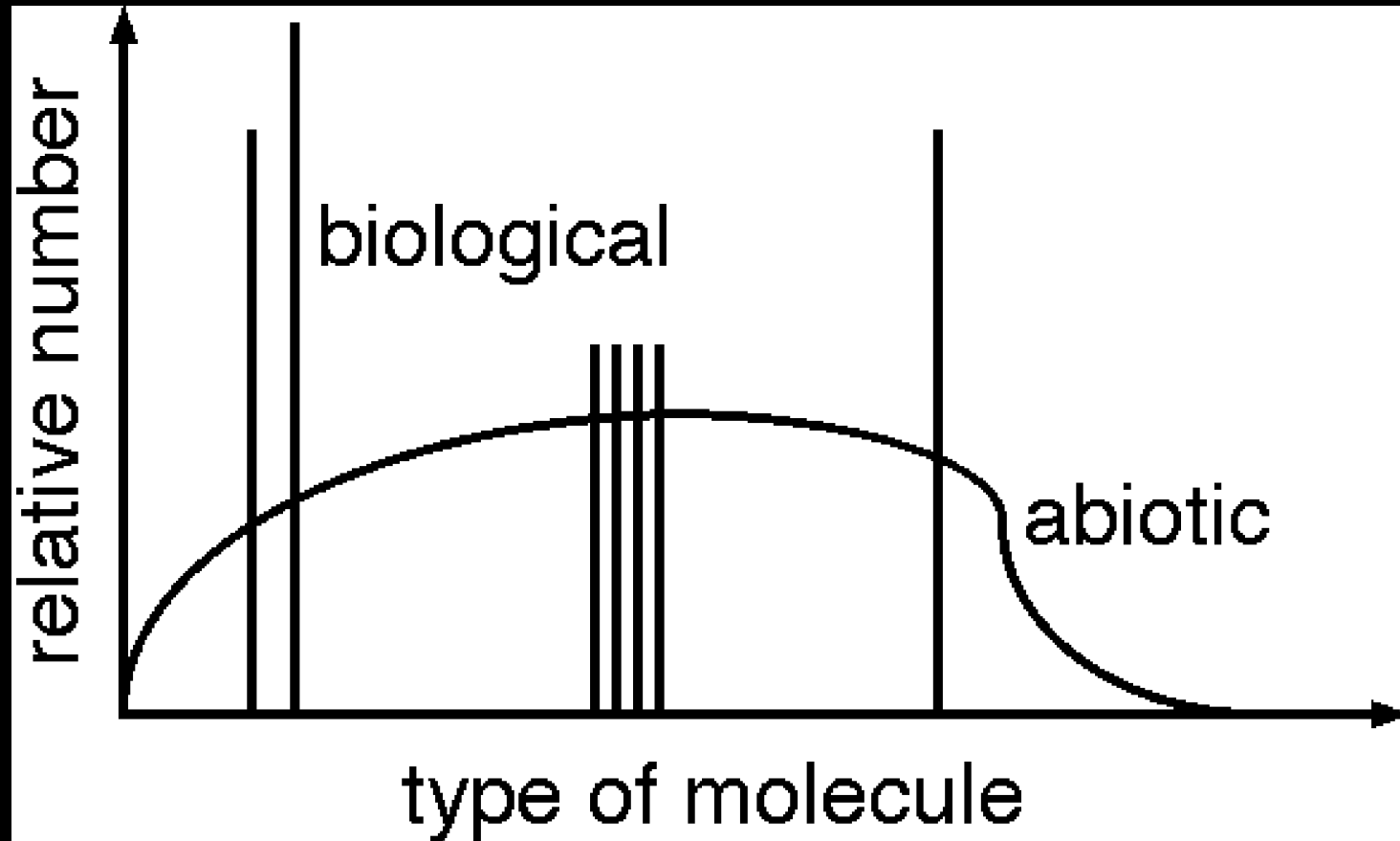


use a tricorder!

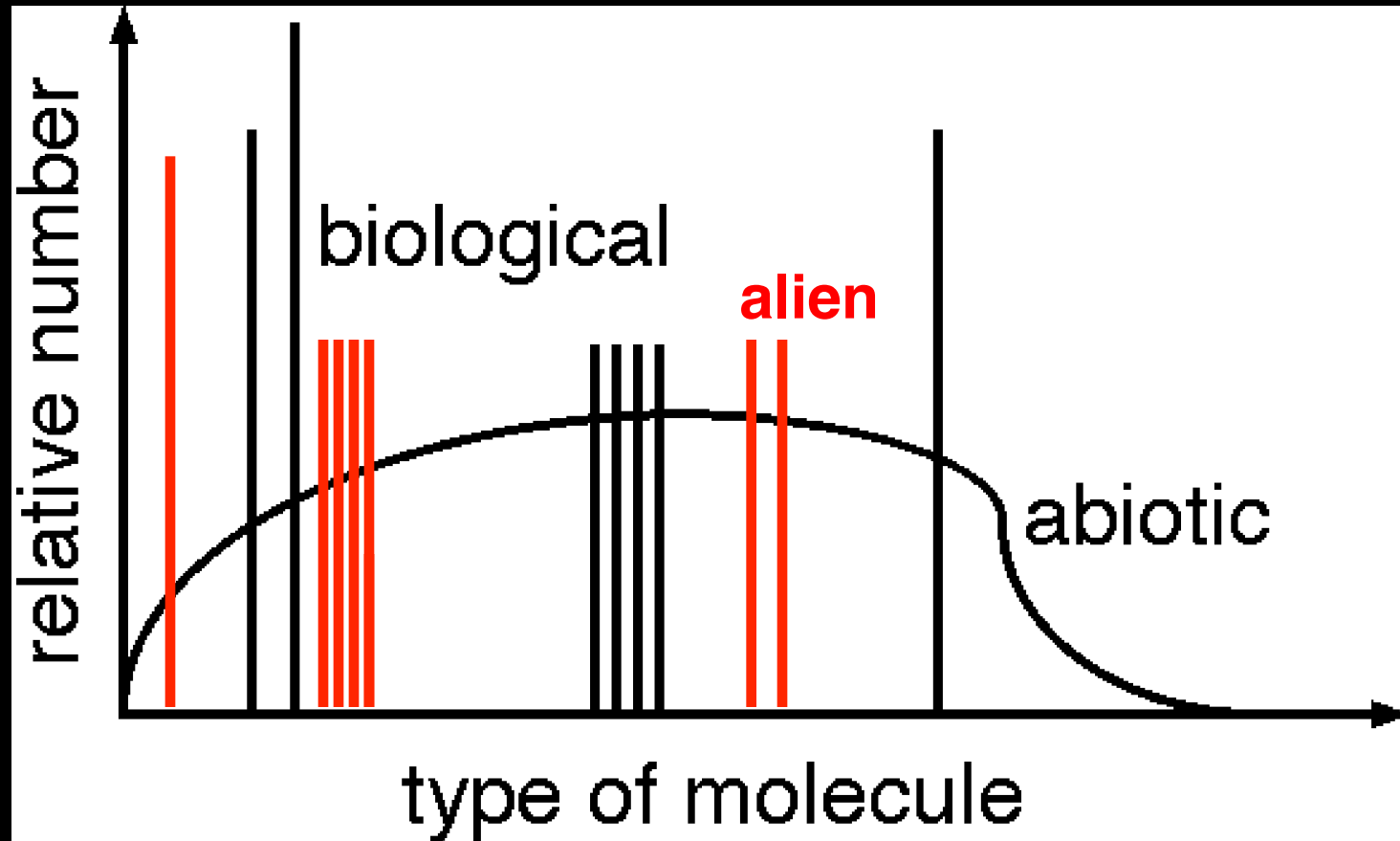


Slide courtesy C. McKay

Abiotic distributions are smooth
Biotic distributions are spiked



Abiotic distributions are smooth
Biotic distributions are spiked



QUESTIONS?

